Hysteresis and the welfare costs of recessions

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Hysteresis and the welfare costs of recessions

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ABSTRACT

This article explores the implications of hysteresis for the welfare costs of recessions by extending the textbook New Keynesian model to include hysteresis. Hysteresis implies that recessions reduce the level of potential output. Famously Lucas (1987, 2003) argued that the welfare costs of business cycles are negligible without hysteresis. This article demonstrates that the welfare costs of recessions are huge (negligible) in the New Keynesian model with (without) hysteresis. The main finding is that an empirically observed degree of hysteresis increases the welfare costs of a recession by a factor of 121. The results are in contrast with Lucas (1987, 2003), who concluded that only changes in the long-term growth rate of consumption have a significant welfare effect. The welfare costs of recessions can be huge without a change in the long-term growth rate of consumption. Hysteresis therefore implies that stabilization policy should respond forcefully to recessions.

1. Introduction

How large are the welfare costs of business cycles? In the dictionary of economics, the welfare costs of business cycles mean the benefits in terms of consumption that households would get from eliminating all business cycles of the economy (Imrohoroglu 2008). The famous conclusions of Lucas (1987, 2003) are that the welfare costs of business cycles and the potential benefits from stabilization policy are negligible. He assumes that risk-averse households would prefer a deterministic consumption path to a risky one with the same mean level of consumption. In his framework, the welfare benefits from eliminating business cycles are insignificant, since business cycles are just temporary fluctuations around an exogenous trend and the observed volatility of aggregate consumption around a trend is small. Only changes in the long-term growth rate of consumption have a substantial welfare effect, and the growth rate is assumed to be independent of aggregate demand. Therefore, Lucas' view was that academic economists and policymakers should focus on the determinants of long-term economic growth rather than stabilization policy.

In a survey article, Imrohoroglu (2008) wrote that many assumptions in the framework of Lucas (1987, 2003) have been challenged. The welfare costs of business cycles may be somewhat greater than Lucas implied. However, Imrohoroglu (2008) concluded that: "the weight of the evidence seems to suggest that they may not be too high for the US economy." More recently, Walentin and Westermark (2018a) stressed that "[a]lthough most people hold the belief that business cycles are costly, the dominating macroeconomic theories of recent decades – both real business cycle theory and new Keynesian theory – imply that the welfare cost of output fluctuations are negligible."

The contribution of this paper is to examine the implications of hysteresis for the welfare costs of recessions. Hysteresis means that recessions lower the level of potential output. I extend the textbook version of the New Keynesian dynamic stochastic general equilibrium (DSGE) model of Gali (2015) to include hysteresis. The empirical observations that recessions have permanent economic costs in terms of lost consumption should lead us to conclude that the welfare costs of business cycles are measured in terms of the welfare value of permanently lost consumption. Barnichon et al. (2018, 4) argued that a financial crisis "can have large costs in terms of societal welfare by causing persistent losses in the level of GDP." In this paper, I measure the welfare costs of business cycles in terms of the value of permanently lost consumption. The volatility of consumption, the approach of Lucas (1987, 2003), would be a good way to measure the welfare losses of business cycles, if business cycles were just temporary fluctuations around a trend.

The literature on the welfare costs of business cycles relies on the traditional view of business cycles. Cerra and Saxena (2017) argue that the problem is that the data do not support this view. The view is shown in Fig. 1(a). They claim that it assumes that supply-side components bring about an upward trend in potential output and demand shocks cause temporary fluctuations around a trend. A recession is a temporary drop in output, which bounces back to its pre-recession trend during the recovery. New research has found that recessions may have a permanent effect on the level of output relative to the pre-recession trend. Ball (2014) found that the damage to potential output is almost as great as the

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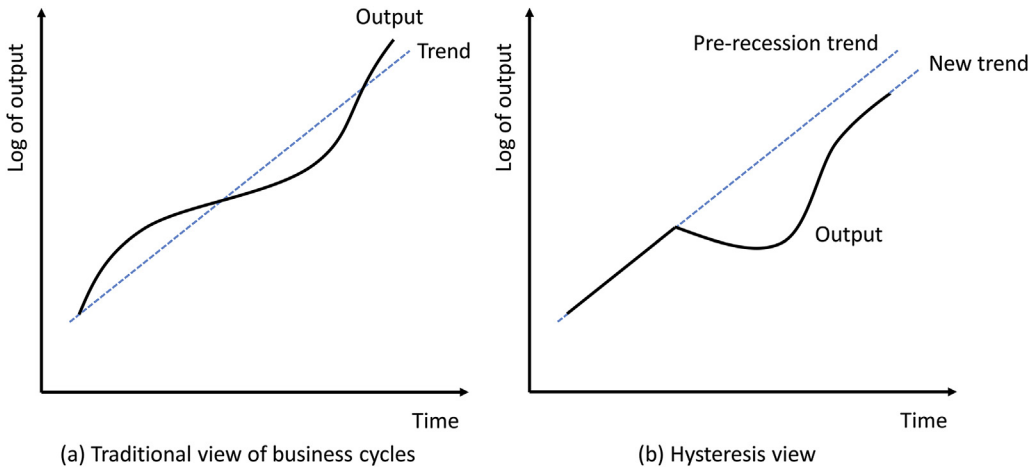

Fig. 1. Views of business cycles.

temporary deviation of actual output from its pre-recession trend in most OECD countries. Rawdanowicz et al. (2014) discovered that one percentage point in the negative output gap reduced potential output by an average of 0.4% in OECD countries in the Great Recession. Blanchard et al. (2015) discovered that two-thirds of recessions are followed by low output relative to the pre-recession trend even after the recovery phase of the business cycle. Martin et al. (2015) also did not find empirical support for the traditional view. They emphasized that the hysteresis effect raises questions about how we should model potential output around recessions. The hysteresis view of the present paper, shown in Fig. 1(b), is that the new trend is parallel to the pre-recession trend, but below it. Empirical studies suggest that an endogenous drop in total factor productivity (TFP) is the main reason for output hysteresis (Adler et al., 2017; Anzoategui et al., 2019). I follow the work of Engler and Tervala (2018), in which negative demand shocks can induce TFP hysteresis via learning-by-doing.

In this paper, I show that the welfare cost of a recession in which the deviation of output from trend is 3% is only 0.6% of consumption in the basic New Keynesian DSGE model without hysteresis. The welfare cost of a recession obviously depends on its size, which is based on Martin et al. (2015). They find that the average deviation of output from the pre-recession trend one year after the start of a recession is roughly 3%. The welfare cost is measured as the net present value of the percentage of initial consumption that the household is willing to pay in order to avoid the recession. In the textbook New Keynesian model, an average-sized recession causes a very short-lived decline in consumption. Consequently, the welfare loss is negligible in the absence of hysteresis. My finding is consistent with Walentin and Westermark (2018a), who pointed out that in New Keynesian models, the welfare costs of inflation variability are "a fraction of a percent of average utility."

The main finding of this paper is that hysteresis has drastic consequences for the welfare costs of recessions. Rawdanowicz et al. (2014, 8) defined the hysteresis parameter as "the impact of one percentage point of the negative output gap on reducing potential output". They find that hysteresis is 0.1 for the U.S. In this paper, I show that this small degree of hysteresis increases the welfare cost of a recession – by a factor of 47 – to 27.3% of consumption in a New Keynesian model. This result may underestimate the welfare costs of recessions, because Rawdanowicz et al. (2014) discovered that the average degree of hysteresis in OECD countries is 0.4. In this paper, I show that this extent of hysteresis implies that the welfare costs of a recession increases to 70%. Hence, a realistic extent of output hysteresis raises the welfare loss by a factor of 121. The reason for the massive welfare loss is a permanent fall in the level of consumption. The welfare loss is dependent on the depth of the recession. The deeper the recession is, the higher the welfare loss is. It is worth observing that the model with hysteresis can match the empirical observations of Jorda et al. (2020). They find that monetary shocks cause TFP and output hysteresis. The basic New Keynesian model is unable to match these observations.

My results in this article are in sharp contrast with Lucas (1987, 2003) and the associated literature, which concluded that only changes in the long-term growth rate of consumption have a significant welfare effect. Walentin and Westermark (2018b), the most directly related paper, found that *employment* hysteresis raises the welfare costs of recessions by a factor of six in their basic case. My findings show that *TFP* hysteresis, which creates a realistic extent of output hysteresis, increases the welfare loss significantly more. In addition, the framework of Walentin and Westermark (2018b) is inconsistent with the empirical evidence of Martin et al. (2015) and Jorda et al. (2020). They show that employment returns to the old trend after normal recessions and monetary shocks. I conclude that the welfare costs of recessions – in the presence of TFP hysteresis – may be very large and that stabilization policy should be a high priority for academic economists and policymakers.

Section 2 introduces the model. Section 3 presents the parameterization. Section 4 studies the implications of hysteresis for the welfare costs of recessions. Section 5 concludes the paper.

2. Model

Gali (2015, Chapter 3) offers an overview of the New Keynesian framework that has been used extensively to understand business cycles and economic policy. I extend it with hysteresis. The model's features and notation follow Gali (2015) as closely as possible. The size of the economy is normalized to unit size. A continuum of households and firms are indexed by $i \in [0, 1]$.

2.1. Demand side: households

The representative household aims to maximize the utility function

$$U_t = E_0 \sum_{s=t}^{\infty} \beta^{s-t} \left[lnC_s - \frac{N_t^{1+\phi}}{1+\phi} \right], \tag{1}$$

where C_t stands for a consumption index, N_t is the employment (hours worked) of the household, and the Frisch elasticity of labor supply is $1/\phi$. The consumption index is

$$C_t = \left[\int_0^1 (C_t(i))^{\frac{\varepsilon-1}{\varepsilon}} di \right]^{\frac{\varepsilon}{\varepsilon-1}}.$$

where $C_t(i)$ denotes the consumption of good i and ε denotes the elasticity

of substitution between goods. The demand for good i is

$$C_t(i) = \left[\frac{P_t(i)}{P_t}\right]^{-\varepsilon} C_t. \quad (2)$$

$P_t(i)$ denotes the price of good i and P_t is an aggregate price index defined as

$$P_t = \left[\int_0^1 (P_t(i))^{1-\varepsilon} di\right]^{\frac{1}{1-\varepsilon}}.$$

The household's budget constraint is

$$P_t C_t + Q_t B_t = B_{t-1} + W_t N_t + D_t. \quad (3)$$

B_t is the holding of one-period nominal discount bonds held at the end of period t. The bonds pay one currency when maturing in period $t+1$. The price of the bond is $Q_t = 1/(1+i_t)$, where i_t is the nominal interest rate. W_t denotes the nominal wage, and D_t is nominal dividends of the firms that the household own.

The household's optimality conditions for consumption and employment are

$$Q_t = \frac{\beta P_t C_t}{P_{t+1} C_{t+1}}, \quad (4)$$

$$N_t = \left(\frac{w_t}{C_t P_t}\right)^{\frac{1}{\phi}}. \quad (5)$$

2.2. Supply side: firms and productivity

Output hysteresis can be induced by a permanent fall in employment, capital accumulation or TFP. Martin et al. (2015) found empirically that employment returns to its pre-recession level trend after normal recessions. They also found that investment falls only during deep recessions. Adler et al. (2017) and Furceri et al. (2021) found empirically that deep recessions cause a persistent drop in the level of TFP. Adler et al. (2017) emphasized that TFP hysteresis is the main contributor to significant output losses relative to pre-recession trends. Bardaka et al. (2020) found empirically that negative demand (austerity) shocks have a negative effect on TFP in the short and long term. Anzoategui et al. (2019) found that a significant fraction of the post-Great Recession TFP slowdown was an endogenous response to the fall in demand. Empirical studies hint that TFP hysteresis is likely to the main reason for output hysteresis.

Firms are assumed to produce differentiated goods. The production function is

$$Y_t(i) = A_t(i) N_t(i)^{1-\alpha}, \quad (6)$$

where $Y_t(i)$ is the output of the firm i, A_t is the level of TFP, and $1-\alpha$ is the output elasticity of employment. As in Gali (2015), private capital is omitted from the production function. As in Chang et al. (2002), Tervala (2013), and Engler and Tervala (2018), a change in the level of TFP is determined by the following log-linear equation:

$$\widehat{A}_t(i) = \rho_A \widehat{A}_{t-1}(i) + \mu \widehat{N}_{t-1}(i). \quad (7)$$

$0 \le \rho_A \le 1$ is the persistence of the changes in TFP and μ is the elasticity of TFP with respect to past employment. Hatted variables represent percentage deviations from the initial steady (e.g., $\widehat{A}_t(i) = dA_t(i)/A_0(i)$, where the zero subscript indicates the initial steady state). Equation (7) generates a link between business cycles and potential output: A fall in employment today reduces TFP tomorrow, with an elasticity of μ. TFP depreciates at the rate of $1-\rho_A$. Strictly speaking, hysteresis requires that $\rho_A = 1$. Then a change in employment affects the level of TFP permanently. For computational reasons, however, ρ_A is set at 0.999999. Therefore, a recession has a quasi-permanent effect on TFP and output, but they eventually return to the initial equilibrium.

The firm maximizes its profits

$$\Pi_t(i) = P_t(i) Y_t(i) - W_t N_t(i), \quad (8)$$

subject to the production function (6) and the demand function (2). The optimal price under flexible prices is

$$P_t(i) = \frac{\varepsilon}{\varepsilon - 1} \frac{W_t}{A_t(i)(1-\alpha) N_t(i)}. \quad (9)$$

Under flexible prices, the price is a constant mark-up over the marginal cost, which is

$$MC_t(i) = \frac{W_t}{A_t(i)(1-\alpha) N_t(i)}.$$

As in Calvo (1983), firms can set their prices with the probability of $1-\theta$ in each period. It is independent of the time since the last price adjustment. The firm seeks to maximize

$$\max_{P_t(i)} V_t(i) = \sum_{s=t}^{\infty} \theta^{s-t} \Lambda_{t,s} \pi_s(i),$$

where $\Lambda_{t,s}$ is the stochastic discount factor between periods t and s. The solution is

$$P_t(i) = \left(\frac{\theta}{\theta - 1}\right) \frac{\sum_{s=t}^{\infty} \theta^{s-t} \Lambda_{t,s} C_s \left(\frac{1}{P_s}\right)^{-\varepsilon} MC_s}{\sum_{s=t}^{\infty} \theta^{s-t} \Lambda_{t,s} C_s \left(\frac{1}{P_s}\right)^{-\varepsilon}}.$$

A log-linearized version of it is

$$\widehat{P}_t(z) = \beta\gamma \widehat{P}_{t+1}(i) + (1-\beta\gamma)\left(\widehat{W}_t - \widehat{A}_t(i) + \alpha \widehat{N}_t(i)\right).$$

The change in the optimal price is a weighted average of the changes in current and future marginal costs. A reduction in TFP increases the optimal price.

2.3. Monetary policy

In the basic New Keynesian framework, including Gali (2015), monetary policy is characterized by the Taylor rule (see Taylor 1993). The central bank adjusts the interest rate based on the deviations of inflation and output from their targets. In this paper, I assume that a source for a recession is a drop in demand. I assume that a monetary shock causes a recession and a negative output gap. This brings about a reduction in employment, which then reduces the level of TFP, and thus potential output. In this type of analysis, it makes little sense to have the output gap in the monetary policy rule. The central bank follows a log-linear Taylor rule with interest rate smoothing

$$\widehat{i}_t = (1-\rho_i)\varphi_\pi \Delta \widehat{P}_t + \rho_i \widehat{i}_{t-1} + \omega_t. \quad (10)$$

Coefficient ρ_i measures the degree of interest rate smoothing, φ_π is the coefficient for inflation in the monetary policy rule, Δ is the first-difference operator, and ω_t represents unexpected monetary shocks. I wish to emphasize that I do not argue that monetary policy shocks are the main cause of recessions; a positive monetary policy shock is just a practical source for a recession in the model.

2.4. Initial steady state

All firms are identical. Firms that set a price, in any period, choose the same price and output. The initial level of employment, which is needed

in welfare analysis, can be solved using equations (5), (6) and (9)

$$N_0 = \left[\frac{(\varepsilon-1)(1-\alpha)}{\varepsilon}\right]^{\frac{1}{1+\phi}}. \quad (11)$$

3. Parameterization

The baseline parameterization of the model, shown in Table 1, follows Gali (2015) as much as possible. Periods represent quarters and the discount factor (β) is set at 0.99. This implies a 4% steady state annual real interest rate. The elasticity of substitution of goods (ε) is set at 9. It implies a 12.5% markup over the marginal cost in the steady state. The Calvo parameter (θ) is set at 0.75. This means that the average price duration is one year. α is set at 0.25. This implies that the elasticity of output with respect to employment is 0.75. The coefficient for inflation (φ_π) in the Taylor rule is set at 1.5.

The monetary policy rule differs from Gali (2015) because of interest rate smoothing. The smoothing parameter (ρ_i)is set at 0.8. This is a common value in the New Keynesian literature and is consistent with Clarida et al. (2000).

The value of the Frisch elasticity of labor supply has been debated, partly because micro and macro elasticities differ greatly. The micro elasticity typically refers to the Frisch elasticity of individuals' hours of work and it is estimated using micro data. The macro elasticity refers to the elasticity of the aggregate hours worked in the economy and it is estimated using macro data. In a review, Whalen and Reichling (2017) argued that estimates of the Frisch elasticity based on macro data are much larger. They found that estimates of the micro elasticity for the intensive margin range from zero to more than one. Keane and Rogersson (2012) found that small estimates for the micro elasticity are fully consistent with the large macro elasticities. They concluded that the macro elasticity exists in the range of 1–2. Gali (2015) sets it at 0.2. It may be too small a value at the macro level. I setϕ at one, so the Frisch elasticity is one. Gali et al. (2007), for example, use this value in analyzing the welfare costs of business cycles.

A near unit persistence of TFP is meant to serve as a reduced-form mechanism to capture long-lasting effects of recessions. The persistence of TFP (ρ_A) is set at 0.999999. Consequently, a recession has a quasi-permanent effect on the level of TFP and output. This is consistent with empirical evidence. The elasticity of TFP with respect to employment (μ) is a crucial parameter since it determines the degree of hysteresis. Chang et al. (2002) estimated that it is 0.11. It is chosen as the baseline value. However, the welfare costs of recessions are very sensitive to it. Therefore, I study in detail how the main results depend on it.

Rawdanowicz et al. (2014) found that 25 out of 32 OECD countries suffered from hysteresis in the Great Recession. They discover that the hysteresis parameter is 0.1 in the U.S. and 0.3 in the euro area. The average degree of hysteresis, including countries without hysteresis, is 0.4. The median value is 0.35. In the present model, following Engler and Tervala (2018), the degree of hysteresis is measured as the ratio of the fall in output in the 20th period, when prices have fully adjusted, to the fall in output in the first period. Under the baseline parameterization, the degree of hysteresis is 0.21. I vary the elasticity of TFP with respect to employment within the range of 0–0.29. So, the degree of hysteresis is in the range of 0–0.4.

The size of the contractionary monetary shock is set so that the depth of a recession matches the empirical estimates on the effects of recessions on the deviation of output from a trend. Martin et al. (2015) studied the consequences of recessions on the long-term level of GDP in 23 advanced economies over 40 years. They found that the average deviation of GDP from the pre-recession trend one year after the beginning of a recession is roughly 3%. Therefore, I set the size of a contractionary monetary shock so that it would bring about a 3% deviation of output. Under the baseline parameterization and the presence of hysteresis, the monetary shock is set at 325 basis points.[1]

Table 1
Baseline parameterization of the model.

	Baseline value	Description	Reference
β	0.99	Discount factor	Gali (2015)
ε	9	Elasticity of substitutability	Gali (2015)
α	0.25	$1-\alpha$ is the output elasticity of labor	Gali (2015)
θ	0.75	Calvo parameter	Gali (2015)
φ_π	1.5	Coefficient for inflation in the monetary policy rule	Gali (2015)
ρ_i	0.8	Interest rate smoothing	Clarida et al. (2000)
ϕ	1	Inverse of the Frisch elasticity	Gali et al. (2007)
ρ_A	0.999999	Persistence of TFP changes	Assumption
μ	0.11	Elasticity of TFP with respect to employment	Chang et al. (2002)

4. Welfare costs of recessions

4.1. Lucas' view

Lucas (1987, 2003) analyzed the welfare effects of eliminating consumption fluctuations, considering a representative household, which is given a consumption stream

$$C_t = Ae^{gt}e^{-(0.5)\delta^2}\varepsilon_t.$$

A is the initial level of consumption, g is the growth rate of consumption, δ is the standard deviation of the natural logarithm of consumption, and ε_t is a log-normally distributed random shock. The preferences are

$$U_t = E_0\sum_{t=0}^{\infty}\beta^t\left[\frac{1}{1-\gamma}C_t^{1-\gamma}\right],$$

where E_0 denotes the expectations operator, $0<\beta<1$ denotes the discount factor, and γ is the relative risk aversion parameter. A risk-averse household prefers a deterministic consumption path to a risky one with the same mean. Lucas measured the utility difference in consumption equivalent terms, denoted by λ, so that the household is indifferent between the deterministic consumption path and the risky path. The welfare cost of business cycles is

$$\lambda \cong \frac{1}{2}\gamma\delta^2.$$

It depends on the size of the consumption risk and the risk aversion for it. Lucas (2003) estimated that the standard deviation of the logarithm of real per capita consumption is 0.032 in the U.S. In the baseline calculation, he assumes log utility for consumption ($\gamma = 1$). Therefore, Lucas (2003) concluded that the welfare cost is 0.05% of consumption. In Lucas (1987), the welfare loss is 0.008%, because the standard deviation of consumption is set at 0.013.

4.2. Method of welfare analysis

I evaluate the welfare losses of recessions as a percentage of initial consumption that the household in the case without a recession is willing to pay to avoid the recession and thus to be as well off in the recession case as in the case without the recession. This follows the idea of Lucas (1987, 2003) and a more recent approach of Schmitt-Grohe and Uribe (2007). Let $\{C_s^{NR}, N_s^{NR}\}_{s=t}^{\infty}$ be the consumption and employment paths with no recession (NR). Then the net present value (NPV) of welfare is

[1] The model is solved using Klein's (2000) method and McCallum's (2001) software.

$$U_{NPV}^{NR} = \sum_{s=t}^{\infty} \beta^{s-t} \left[\ln\left(C_s^{NR}\right) - \frac{\left(N_s^{NR}\right)^{1+\phi}}{1+\phi} \right].$$

I define λ^f as the NPV of the welfare cost of a recession (R) relative to a case without the recession. For now, I measure it as a *fraction* of consumption. Let U_{NPV}^{R} denote the NPV of welfare in the recession case. Then

$$U_{NPV}^{R} = \sum_{s=t}^{\infty} \beta^{s-t} \left[\ln\left(\left(1-\lambda^f\right)C_s^{NR}\right) - \frac{\left(N_s^{NR}(z)\right)^{1+\phi}}{1+\phi} \right].$$

$$U_{NPV}^{R} = \frac{1}{1-\beta}\ln\left(1-\lambda^f\right) + U_{NPV}^{NR}.$$

The next step is to solve for λ^f. In addition, the welfare cost of a recession is now expressed as the *percentage* of consumption (denoted by λ).

$$\lambda = -100 \times \left[\exp(1-\beta)\left(U_{NPV}^{R} - U_{NPV}^{NR}\right) - 1\right]. \tag{12}$$

The utility function's first-order Taylor expansion is

$$dU_{NPV} = U_{NPV}^{BS} - U_0 = \sum_{s=t}^{\infty} \beta^{s-t} dU_s^{BS} = \sum_{s=t}^{\infty} \beta^{s-t} \left(\widehat{C}_s^{BS} - (N_0)^{1+\phi} \widehat{N}_s^{BS} \right).$$

Welfare in the case without business cycles is the same as in the initial equilibrium. Therefore, the equation above can be substituted into equation (13) to obtain

$$\lambda = -100 \times \left[\exp(1-\beta) \sum_{s=t}^{\infty} \beta^{s-t} \widehat{C}_s^{BS} - (N_0)^{1+\phi} \widehat{N}_s^{BS} \right) - 1 \Bigg]. \tag{13}$$

Equation (13) calculates the welfare costs of recessions as the percentage of initial consumption that the household in the case without a recession is willing to pay in order to avoid the recession and be as well off in the recession case as in the case without the recession. In a figure, however, I depict the welfare cost in one period

$$\lambda_t = 100 \times \left[\exp(1-\beta) \left(\widehat{C}_s^{BS} - (N_0)^{1+\phi} \widehat{N}_s^{\mathrm{BS}} \right) - 1 \right].$$

The welfare loss of business cycles typically refers to equation (13), which measures the NPV.

4.3. Degree of hysteresis and the costs of recessions

Fig. 2 displays the impulse responses of the main variables to a monetary shock. The horizontal axes show time. The vertical axes typically display percentage deviations from the initial steady state. Inflation and interest rate, however, are expressed as percentage point deviations in annual terms. The welfare cost is denoted in the percentage of initial consumption. The solid lines represent the case without hysteresis. The dashed lines represent the case with hysteresis. As discussed in Section 3, the size of the monetary shock is always set so that it causes a three percent fall in output.

Without hysteresis, the model is virtually identical to Gali (2015, Chapter 3) and the effects of a monetary policy shock are identical to those in it. Only the size of the shock is different (in this paper 340 basis points, in Gali (2015) 100 points). An increase in the nominal interest rate, shown in Fig. 2(f), causes a rise in the real interest rate. This subsequently causes a contraction in household consumption. Consequently, output (Panel (a)) and employment (Panel (b)) fall in the short term. In the long term, prices adjust and consumption, output, employment and welfare (Panel (d)) return to their initial levels. In imperfectly competitive economies, identical declines in consumption and employment cause a fall in welfare. Fig. 2(d) shows a very short-lived fall in welfare. Table 2 shows that the welfare loss of a recession is only 0.6% of consumption.

In the presence of hysteresis, the size of the monetary shock is reduced to 325 basis points so that the initial drop in output remains at 3%. Equation (7) implies that a fall in demand and employment, caused by a rise in the real interest rate, has a persistent and negative effect on TFP, shown in Fig. 2(c). TFP hysteresis brings about a permanent fall in

Table 2
Hysteresis and the welfare costs of recessions.

Elasticity of TFP with respect to employment	Hysteresis	Welfare cost of a recession
0	0	0.578
0.025	0.050	15.6
0.05	0.10	27.3
0.076	0.15	37.0
0.11 (baseline)	0.21	47.1
0.14	0.25	53.6
0.18	0.30	60.1
0.227	0.35	66.7
0.29	0.40	70.2

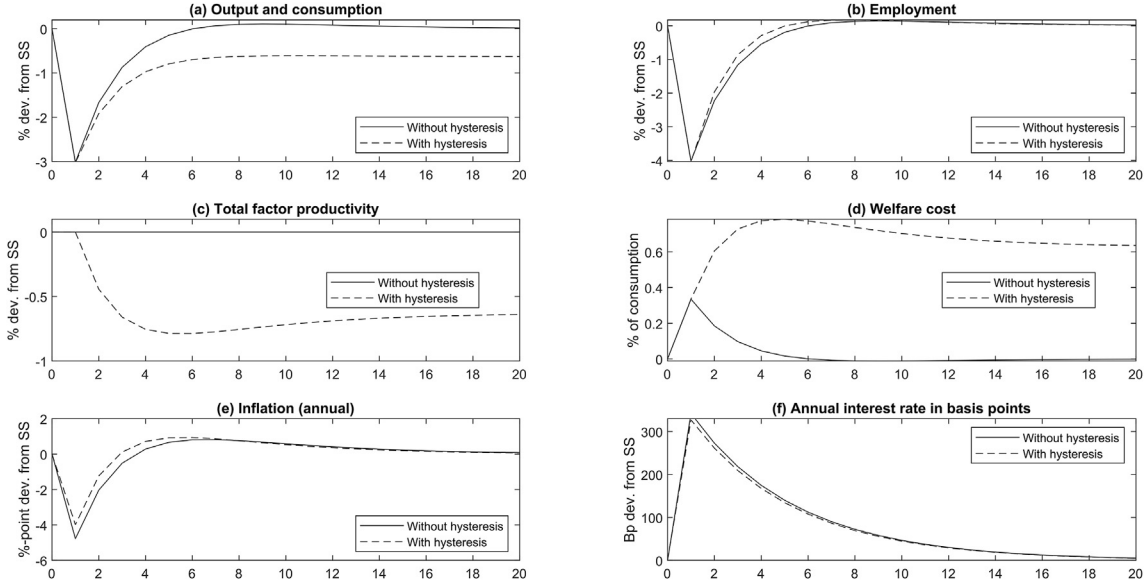

Fig. 2. Dynamic responses of key variables without and with hysteresis.

aggregate supply, causing output hysteresis and a permanent fall in consumption, shown in Fig. 2(a). However, employment reverts to its initial level (Fig. 2(b)). In the medium and long term, households experience a fall in welfare (Fig. 2(d)), due to a reduction in consumption and unchanged employment. Table 2 shows that hysteresis increases the welfare cost of a recession from 0.6% to 47.1%.

Moran and Queralto (2018) found empirical evidence that an expansionary monetary policy has a positive effect on TFP. The medium-term effect is stronger than the short-term effect. However, the TFP effect is long-lived. The behavior of TFP in this model is in line with this evidence. Jorda et al. (2020) found empirically that output and TFP are affected for a very long time. They do not revert to their pre-shock trends. However, employment (total hours worked) reverts swiftly to the pre-shock trend. Fig. 2 shows that the responses of output, TFP and employment in the model with hysteresis are fully consistent with the empirical observations. The model without hysteresis, i.e. the basic New Keynesian model, cannot match the observed behavior of output and TFP.

As mentioned, the degree of hysteresis is defined as the ratio of the drop in output in the 20th period to the drop in output in the first period. This definition is consistent with the definition of Rawdanowicz et al. (2014), because the drop in first-period output measures the output gap in the first period. In the baseline case ($\mu = 0.11$), the degree of hysteresis is 0.21. This is in the middle range of the estimates of Rawdanowicz et al. (2014).

Next, I analyze the dependence of the welfare losses of recessions on the degree of hysteresis. The elasticity of TFP with respect to employment is varied so that the degree of hysteresis is at the desired level. At the same time, the size of the monetary policy shock was changed so that the fall in output would remain at 3% (the higher the degree of hysteresis, the smaller the monetary shock). As mentioned, Rawdanowicz et al. (2014) discovered that the hysteresis parameter is 0.1 in the U.S. and 0.3 in the euro area. In Fig. 3, the solid lines represent the case where hysteresis is 0.1 (μ is set at 0.05), the dashed lines represent the baseline case where hysteresis is 0.21 ($\mu = 0.11$), and the dashed lines with a star represent the case where hysteresis is 0.3 ($\mu = 0.18$).

Table 2 highlights that the welfare losses of recessions are highly sensitive to changes in the degree of hysteresis. Fig. 3(a) shows that the higher the degree of hysteresis, the larger the fall in consumption. The hysteresis estimate of Rawdanowicz et al. (2014) for the U.S. (0.1) implies that the welfare cost increases to 27.3% of consumption. This is 47 times the welfare cost without hysteresis. This may underestimate the welfare cost of some recessions, since Rawdanowicz et al. (2014) estimated that the average degree of hysteresis in OECD countries during the Great Recession was 0.4. Table 2 shows that this degree of hysteresis implies that the welfare cost of a recession is as high as 70% of consumption. It is 121 times the welfare cost without hysteresis. In this model, the degree of hysteresis is 0.4, when the elasticity of TFP with respect to employment set at 0.29. This is higher than the empirical estimate (0.11) of Chang et al. (2002). However, Jorda et al. (2020) estimated that the elasticity of TFP with respect to output fluctuations is 0.42. With this estimate, equations (6) and (7) and the assumption that $\alpha = 0.25$ imply that the elasticity of TFP with respect to employment is 0.32. Therefore, the link between business cycles and TFP is likely to be stronger than the estimate of Chang et al. (2002) suggests.

4.4. Related literature

As mentioned, Lucas (2003) finds that the welfare loss is 0.05% in each period, when the standard deviation of consumption is 3.2%. The numbers in the present paper are not fully comparable with his numbers, since I focus on analyzing the NPV of the welfare cost of a 3% drop in consumption. However, Fig. 3(d), shows the welfare cost in each period. When the extent of hysteresis is in the range to 0.1 to 0.3, the welfare cost ranges from 0.32% to 0.92% of initial consumption in the 20th period.

Since the Lucas (1987) publication, several studies have challenged its main findings. Barlevy (2005) classified these studies according to the features of Lucas' model that they modify. The first group has modified preferences or the persistence of shocks (including Dolmas 1998; Pemberton 1996; Obstfeld 1994; Otrok 2001; Tallarini 2000). For example, a higher degree of risk aversion increases the welfare costs of business cycles. Barlevy (2005) argued that these studies find that the losses of business cycles are small, although they may be higher than in Lucas (1987). Dolmas (1998) finds that welfare costs can be up to 20% of consumption in each period if shocks affect the long-term growth rate of consumption. However, the result supports Lucas' (1987) claim that the welfare costs of a change in the long-term growth rate of consumption are substantial.

The second group of studies (including De Santis 2007, Chatterjee and Corbae 2007, Imrohoroglu 1989 and Storesletten et al., 2001) has calibrated consumption risk to match household data rather than aggregate data, since the consumption of some individuals declines much more during recessions than aggregate consumption (Barlevy 2005). Some of these studies have suggested that the welfare losses of business

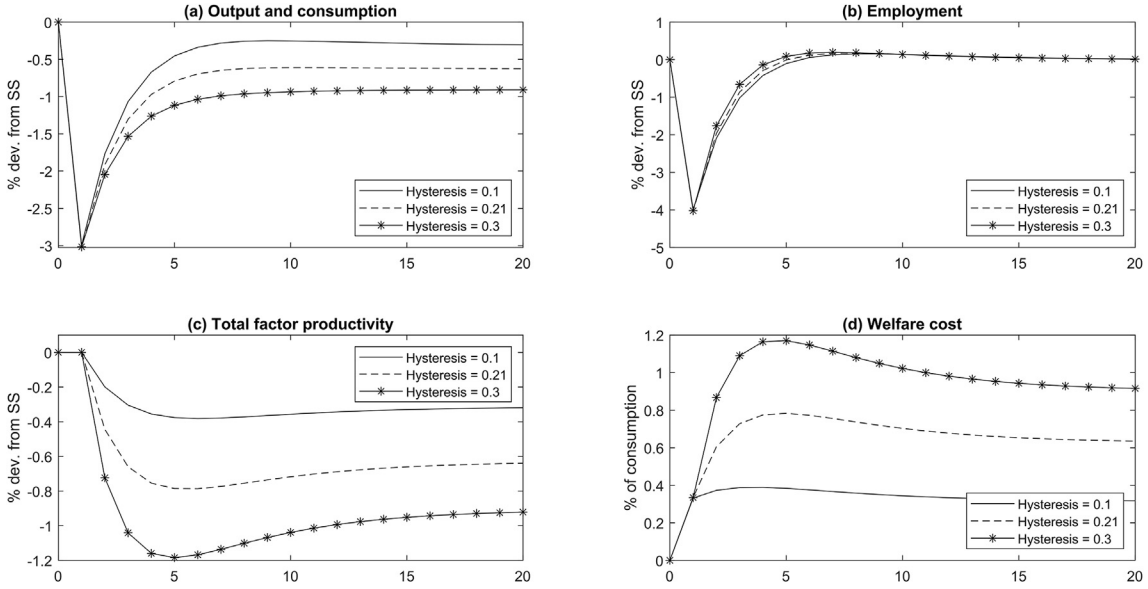

Fig. 3. Dynamic responses of key variables with hysteresis.

cycles are somewhat higher than Lucas (1987, 2003) estimated.

The third group of studies, including Epaulard and Pommeret (2003), assumes that stabilization policy affects long-term growth through investment. This channel increases the welfare loss of business cycles, but it is still less than 0.5% in each period. Fig. 3(d) shows that under the baseline parameterization, the welfare cost in the 20th period is somewhat higher, even without growth effects. However, in the growth model of Barlevy (2004), the welfare loss can be much higher. In his model, a rise in investment accelerates economic growth less than an identical fall decreases it. Therefore, eliminating business cycles increases the growth rate. It is questionable to interpret this as the welfare costs of business cycles. It provides support for Lucas' (1987, 2003) view that changes in the long-term growth rate of consumption have a significant welfare effect.

The fourth group of studies, including those by Cohen (2000), Iliopulos et al. (2019), Jung and Kuester (2011) and Walentin and Westermark (2018b), assumes that stabilization policy affects the level of consumption. In the framework of Lucas (1987, 2003), business cycles are deviations from a trend that leave the long-run level of consumption unchanged and the welfare costs of recessions are partly offset by the benefits of booms. Cohen (2000) criticizes the work of Lucas (1987), in which the aim of stabilization policy is to eliminate both above-trend and below-trend fluctuations in consumption. He considers that stabilization policy is aimed at eliminating only below-trend movements, thus allowing an increase in the mean level of consumption. The welfare benefit of eliminating all below-trend movements is 1% of consumption in each period. In the present model, when the extent of hysteresis is in the range to 0.3 to 0.4, the welfare loss of a single recession ranges from 0.92% to 1.2% of initial consumption in the 20th period.

Walentin and Westermark (2018a) stressed that the welfare losses of business cycles are insignificant in New Keynesian DSGE models. In Gali et al. (2007), the welfare costs of all postwar U.S. business cycles are only 0.01% under their baseline parameterization (log utility for consumption and the Frisch elasticity of one). Moreover, they analyzed the welfare costs by measuring the cumulative welfare losses over the recession. This is comparable with the method used in the present paper. Under their baseline parameterization, the welfare cost of the U.S. recession at the beginning of the 1990s was 2.3%. In the present model, the welfare cost in the absence of hysteresis (0.6%) is smaller than that in Gali et al. (2007), because of the milder and shorter recession. However, the main finding of this paper is that hysteresis has drastic implications for the welfare costs of recessions in the basic New Keynesian model. The welfare loss of a moderate recession can be up to 70%, 30 times higher than the finding of Gali et al. (2007).

Iliopulos et al. (2019) developed a nonlinear DSGE model with financial and labor frictions. They found that frictions raise aggregate volatility. This increases the welfare costs of business cycles, consistent with the second group of studies. Furthermore, frictions imply that the welfare losses of recessions are higher than the benefits of booms. Therefore, a rise in the mean level of consumption would be very beneficial. They found that financial and labor frictions can increase the welfare costs of business cycles by a factor of 21. This paper shows that hysteresis has more drastic implications for the welfare costs of recessions, since it can increase them by a factor of 121.

The most directly related paper is that by Walentin and Westermark (2018b). They used a labor market search and matching model with human capital (learning on-the-job and skill losses during unemployment). A recession reduces employment. The learning on-the-job feature means that it diminishes human capital. This creates hysteresis in employment and eliminating business cycles increases the long-term level of consumption. The welfare loss of business cycles in the absence of human capital dynamics is 0.26% in each period. Human capital dynamics increase it to 1.52%. Hence, employment hysteresis increases the welfare loss of business cycles by a factor of six. The findings of this paper show that modelling the effects of recessions on potential output through TFP increases the welfare costs of recessions considerably more. The average degree of hysteresis in OECD countries (0.4) increases them by a factor of 121.

4.5. Sensitivity analysis

I explore whether the welfare costs of recessions are responsive to changes in parameter values. Table 3 shows the results. Row 1 presents the baseline result. In the present model, periods represent quarters. Strictly speaking, the baseline result is that the welfare cost of a recession is 47.1% of quarterly consumption. Lucas (1987) sets the discount factor at 0.95 so his analysis measures the welfare loss of business cycles as a percentage of annual consumption. In row 2, I use the same value. The welfare cost measured as a percentage of annual consumption is almost the same (46.2%).

A difference from Lucas (1987, 2003) is the endogeneity of labor supply. This feature may affect the welfare costs of consumption risks. The elasticity of substitution of goods affects the level of initial employment (equation (11)) and this affects the welfare cost of business cycles (see equation (13)). In row 3 it is reduced to 6, a common value in the New Keynesian literature. In row 4 it is increased to 21. Table 3 shows that the main finding is robust to change in it.

Gali et al. (2007) found that the welfare loss can be responsive to the Frisch elasticity of labor supply. Row 5 shows the welfare loss when it is set at 0.2, following Gali (2015). I underline that the row shows the effects of varying the Frisch elasticity while I increase the size of the shock so that the fall in output remains at 3%. If I decrease the Frisch elasticity and keep the size of the shock constant, then the recession would be smaller. In this case, the welfare loss of a recession would be smaller. Row 5 illustrates that lower Frisch elasticity reduces hysteresis and the welfare costs of recessions. Row 6 shows that doubling the Frisch elasticity from the baseline value of 1–2 has a minor effect on the welfare costs.

The output elasticity of labor is $1-\alpha$. In row 7, $\alpha$is set at 0.33. It is commonly used in macroeconomics, while the baseline parameterization followed Gali (2015). It shows that the welfare cost increases mildly to 49.6%. In row 8, $\alpha$is set at zero and output is linear in labor. Gali et al. (2007) argue that this assumption is line with the view that changes in the capital stock are negligible at business cycle frequencies, and that the capital utilization rate is proportional to employment. Row 8 shows that the welfare cost decreases to 41%.

Some studies suggest that prices adjust more often than once a year. Bills and Klenow (2004) found the median duration of prices is 5.5 months. This corresponds to the Calvo parameter of 0.5. This is supported by Smets and Wouters (2007). In row 8, $\theta$is set at 0.5. It shows that the welfare cost decreases to 38%. A fall in consumption becomes somewhat shorter and smaller when prices are adjusted more frequently.

The parameters that govern the damage to potential output are the elasticity of TFP with respect to employment and the persistence of TFP, which affects the duration of the damage. Chang et al. (2002) discovered that the persistence of TFP is 0.8 using micro-level data from 1953 to 1997. However, Engler and Tervala (2018) argued that this estimate is not relevant for recessions. It does not create a hysteresis-like response of

Table 3
Sensitivity analysis.

Row	Parameter	Hysteresis	Welfare cost of a recession
1	Baseline	0.21	47.1
2	$\beta = 0.95 (\beta = 0.99)$	0.19	46.2
3	$\varepsilon = 6 (\varepsilon = 9)$	0.21	47.3
4	$\varepsilon = 21 (\varepsilon = 9)$	0.21	47.0
5	$\phi = 5 (\phi = 1)$	0.17	41.3
6	$\phi = 0.5 (\phi = 1)$	0.21	48.1
7	$\alpha = 0.33 (\alpha = 0.25)$	0.22	49.6
8	$\alpha = 0 (\alpha = 0.25)$	0.17	40.8
9	$\theta = 0.5 (\theta = 0.75)$	0.16	38.1
10	$\rho_A = 0.99 (\rho_A = 0.999999)$	0.17	27.6
11	$\rho_A = 0.96 (\rho_A = 0.999999)$	0.091	12.5
12	$\rho_A = 0.86 (\rho_A = 0.999999)$	0	4.8

output, since TFP returns rapidly to the initial level. Broadbent et al. (2019) found that the persistence of TFP in the traded goods sector is in the range of 0.95–0.99. In rows 10–12, the persistence is reduced from 0.999999 to 0.99, 0.96 and 0.86. They show that the persistence of TFP has a significant effect on the welfare cost of business cycles. When the persistence is 0.96, the value used by Reifschneider et al. (2015), the negative effect of a recession on TFP fades away quite quickly and the reduction in consumption is relatively short-lived. This implies that the welfare cost is drastically reduced to 12.5%. However, in this case it is misleading to talk about hysteresis because output returns to the initial level quite rapidly. This is in contrast with the empirical studies showing that recessions have a highly persistent or permanent GDP effect. When the persistence of TFP is set at 0.86, output returns very rapidly to the initial level and the welfare cost decreases to 4.8%. This is still much higher than the baseline number without hysteresis (0.6%).

In summary, the main results are responsive to the elasticity of TFP with respect to employment and the persistence of TFP. If the elasticity of TFP with respect to employment is low, then the damage of a recession to potential output is weak. Consequently, the welfare cost of a recession is smaller. If the persistence of TFP is not high, then the damage to potential output is short-lived. Hence, the welfare costs of recessions are small. However, the welfare costs of recessions are significant when recessions affect TFP quasi-permanently. The welfare cost of a recession obviously depends crucially on its size and duration.

5. Conclusions

Yellen (2016) has observed that deep recessions often challenge prevailing views about how the economy works and exposed flaws in economists' knowledge. She argued that experiences following the Great Recession indicate that fluctuations in aggregate demand may have a persistent effect on potential output. She highlighted that addressing this topic is essential to the work of economic policymakers. In this paper, I have argued that hysteresis has not properly been taken into account in the study of the welfare effects of recessions. I show that hysteresis has important implications for them. In the basic New Keynesian framework, the welfare costs of recessions are negligible. A small extent of hysteresis, 0.1, raises the welfare cost by a factor of 47 from 0.6% to 27.3% of consumption. A higher degree of hysteresis, 0.4, increases the welfare loss by a factor of 121 to 70%. My results are in contrast with Lucas (1987, 2003), who concluded that the welfare losses of business cycles are unimportant and only changes in the long-term growth rate of consumption have a major welfare effect. In this paper, the welfare costs of a recession can be highly significant even without a change in the long-term growth rate of consumption.

My findings suggest that the welfare costs of recessions may be huge in the presence of hysteresis. Yellen (2016) emphasized that hysteresis implies that policymakers should respond quickly and aggressively to a recession. This reduces the depth and persistence of the recession, and thus limits the damage to potential output. Reifschneider et al. (2015) showed that hysteresis provides a solid motivation for a strong monetary policy response to a recession. Moran and Queralto (2018) stressed that the dependence of aggregate supply on demand raises the stakes over the conduct of monetary policy, compared to the traditional view, which treats the evolution of TFP as exogenous. Engler and Tervala (2018) found that a fiscal expansion becomes desirable in recessions with hysteresis effects, while it is not desirable without hysteresis. More research is needed so we can have a better understanding of the implications of hysteresis for the welfare costs of recessions and the conduct of stabilization policy.

Declaration of competing interest

None.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.econmod.2020.12.012.

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